**Al-Farabi KAZAKH NATIONAL UNIVERSITY**

**Faculty of mechanics and mathematics**

**Educational program for the specialty «Space technics and technology»**

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|  | Approved by the Faculty Scientific Council meetingProtocol №\_\_\_ from \_\_\_\_\_\_\_\_\_\_\_\_ 2016 **Dean of the faculty**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_M. Bektemesov** |

**SULLABUS**

**Module No. \_\_\_ “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_”**

**«\_\_\_\_\_\_\_\_\_» «Numerical methods for optimization control theory»**

master degree, 1 course, spring semester, 3 credits

**Serovajsky Simon, Doctor of Science, Professor, Professor**

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**Aim and problems of the course:**

**Aim:**

Practical solving of optimization control problems.

**Problems:**

Numerical methods for optimization control problems.

**Results:**

Analysis of the solving difficulties of optimization control problems.

**Pre Essential Elements**:

Calculus of variational and optimization methods. Differential equations. Functional analysis

**Post** **Essential Elements**:

Numerical methods for extremum problems. Inverse problems.

**STRUCTURE AND CONTENT OF THE COURSE**

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| --- | --- | --- | --- |
| **week** | **subject** | **hours** | **maximal mark** |
| **Module 1. Introduction** | | | |
| **1** | **Lecture 1. Introduction**. Pontyagin’s maximum principle. Numerical methods for necessary conditions of optimality. | 1 | 0 |
| **Practical work 1**. Pontyagin’s maximum principle. Example | 1 | 3 |
| **Homework 1**. Example of Pontyagin’s maximum principle. | 1 | 10 |
| **Module 2. Sufficiently of the optimality conditions** | | | |
| **2** | **Lecture 2. Sufficiently of the optimality conditions.** Example of the insufficient conditions of optimality. | 1 | 1 |
| **Practical work 2**. Proof of the sufficiently of the optimality conditions. | 1 | 3 |
| **Homework 2**. Proof of the sufficiently of the optimality conditions. | 1 | 10 |
| **3** | **Lecture 3. Sufficiently of the optimality conditions.** Proof of the sufficiently of the optimality conditions. | 1 | 2 |
| **Practical work 3**. Proof of the sufficiently of the optimality conditions. | 1 | 3 |
| **Homework 3.** Proof of the sufficiently of the optimality conditions. | 1 | 10 |
| **4** | **Lecture 4. Singular control.** Examples. | 1 | 1 |
| **Practical work 4**. Examples of singular control. | 1 | 3 |
| **Homework 4**. Examples of singular control. | 1 | 10 |
| **5** | **Lecture 5. Singular control.** Kelly’s condition. | 1 | 2 |
| **Practical work 5**. Kelly’s condition. | 1 | 3 |
| **Homework 5**. Kelly’s condition. | 1 | 10 |
| **Module 3. Existence and uniqueness of the solution** | | | |
| **6** | **Lecture 6. Existence and uniqueness of the optimal control.** Example of the insolvable problem with sufficiently of the optimality condition. | 1 | 1 |
| **Practical work 6.** Uniqueness of the optimal control. | 1 | 3 |
| **Homework 6.** Uniqueness of the optimal control. | 1 | 10 |
| **7** | **Lecture 7. Existence and uniqueness of the optimal control.** Example of the insolvable problem with sufficiently of the optimality condition. | 1 | 2 |
| **Practical work 7.** Existence of the optimal control. | 1 | 3 |
| **Homework 7.** Existence of the optimal control. | 1 | 10 |
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| **Border control 1** |  | **100** |
|  | | | |
| **8** | **Lecture 8. Existence and uniqueness of the optimal control. II.** Example of the insolvable problem without sufficiently of the optimality condition. | 1 | 1 |
| **Practical work 8.** Insolvable problem without sufficiently of the optimality condition. | 1 | 3 |
| **Homework 8.** Insolvable problem without sufficiently of the optimality condition. | 1 | 8 |
| **9** | **Lecture 9. Existence and uniqueness of the optimal control. II.** Example of the insolvable problem without sufficiently of the optimality condition. | 1 | 2 |
| **Practical work 9.** Insolvable problem without sufficiently of the optimality condition. | 1 | 3 |
| **Homework 9.** Insolvable problem without sufficiently of the optimality condition. | 1 | 8 |
| **Module 4. Well-posedness of the optimization control problems** | | | |
| **10** | **Lecture 10. Tihonov’s well-posed problem.** Example of Tihonov’s ill-posed problem.ProofofTihonov’s well-posedness. Regularization methods. | 1 | 1 |
| **Practical work 10.** Tihonov’s well-posed problem. | 1 | 3 |
| **Homework 10.** Tihonov’s well-posed problem. | 1 | 8 |
| **11** | **Lecture 11. Hadamard’s well-posed problem.** Example of Hadamard’s ill-posed problem.ProofofHadamard’s well-posedness. | 1 | 2 |
| **Practical work 11.** Hadamard’s well-posed problem. | 1 | 3 |
| **Homework 11.** Hadamard’s well-posed problem. | 1 | 8 |
| **Module 5. Additions** | | | |
| **12** | **Lecture 12. Optimization problems with isoperimetric conditions.** Necessary conditions of minimum. Example. | 1 | 1 |
| **Practical work 12.** Necessary conditions of minimum for optimization problem with isoperimetric condition. | 1 | 3 |
| **Homework 12.** Necessary conditions of minimum for optimization problem with isoperimetric condition. | 1 | 8 |
| **13** | **Lecture 13. Optimization problems with isoperimetric conditions.** Nonuniqueness of the solutions for the boundary problem. | 1 | 2 |
| **Practical work 13.** Necessary conditions of minimum for optimization problem with isoperimetric condition. | 1 | 3 |
| **Homework 13.** Necessary conditions of minimum for optimization problem with isoperimetric condition. | 1 | 8 |
| **14** | **Lecture 14**. **Bifurcation of extremals.** Cheffey-Infante problem. | 1 | 1 |
| **Practical work 14.** Bifurcation of extremals. | 1 | 3 |
| **Homework 14.** Bifurcation of extremals. | 1 | 8 |
| **15** | **Lecture 15. Bifurcation of extremals.** Bifurcation of solutions and bifurcation of extremals. | 1 | 2 |
| **Practical work 15.** Bifurcation of solutions. | 1 | 3 |
| **Homework 15.** Bifurcation of solutions. | 1 | 8 |
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| **Border control 2** |  | **100** |
|  | **Examination** |  | **100** |
|  | **TOTAL** |  | **100** |

**LITERATURE**

**Basic:**

1. Serovajsky S. Practical Course of the Optimal Control Theory with Examples. – Almaty, Қазақ университеті, 2011.
2. Serovajsky S. Counterexamples in optimal control theory. – Utrecht-Boston, VSP, 2004.
3. Серовайский С.Я. Контрпримеры в теории оптимального управления. – Алматы, Қазақ университеті, 2001.
4. Алексеев В. М., Тихомиров В. М., Фомин С. В. Оптимальное управление. – М., Наука, 1979.
5. Kirk D. E. Optimal Control Theory: An Introduction. – New Jersey, Englewood Cliffs, 2004. <http://www.amazon.com/Optimal-Control-Theory-Introduction-Engineering/dp/0486434842>

**Additional:**

1. Васильев Ф.П. Методы оптимизации. В двух томах. – М.: МЦНМО, 2011.
2. Лутманов С.В. Курс лекций по методам оптимизации. – Ижевск, 2001.
3. Габасов Р., Кириллова Ф. Качественная теория оптимальных процессов. – М., Наука, 1907. – 507 с.
4. Иоффе А. Д., Тихомиров В. М. Теория экстремальных задач. – М., Наука, 1974. – 480 с.
5. Канторович Л. В., Акилов Г. П. Функциональный анализ. – М., Наука, 1977. – 744 с.

АКАДЕМИЧЕСКАЯ Политика курса

Все виды работ необходимо выполнять и защищать в указанные сроки. Студенты, не сдавшие очередное задание или получившие за его выполнение менее 50% баллов, имеют возможность отработать указанное задание по дополнительному графику. Студенты, пропустившие лабораторные занятия по уважительной причине, отрабатывают их в дополнительное время в присутствии лаборанта, после допуска преподавателя. Студенты, не выполнившие все виды работ, к экзамену не допускаются. Кроме того, при оценке учитывается активность и посещаемость студентов во время занятий.

будьте толерантны, уважайте чужое мнение. Возражения формулируйте в корректной форме. Плагиат и другие формы нечестной работы недопустимы. Недопустимы подсказывание и списывание во время сдачи СРС, промежуточного контроля и финального экзамена, копирование решенных задач другими лицами, сдача экзамена за другого студента. Студент, уличенный в фальсификации любой информации курса, несанкционированном доступе в Интранет, пользовании шпаргалками, получит итоговую оценку «F».

За консультациями по выполнению самостоятельных работ (СРС), их сдачей и защитой, а также за дополнительной информацией по пройденному материалу и всеми другими возникающими вопросами по читаемому курсу обращайтесь к преподавателю в период его офис-часов.

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| --- | --- | --- | --- |
| Letter mark | Number mark | % | Traditional mark |
| А | 4,0 | 95-100 | Very good |
| А- | 3,67 | 90-94 |
| В+ | 3,33 | 85-89 | Good |
| В | 3,0 | 80-84 |
| В- | 2,67 | 75-79 |
| С+ | 2,33 | 70-74 | Satisfactory |
| С | 2,0 | 65-69 |
| С- | 1,67 | 60-64 |
| D+ | 1,33 | 55-59 |
| D- | 1,0 | 50-54 |
| F | 0 | 0-49 | Non satisfactory |
| I  (Incomplete) | - | - | «The course is not finished»  (*do not take into consideration of GPA)* |
| P  (Pass) | **-** | **-** | «given a credit»  (*do not take into consideration of GPA)* |
| NP  (No Рass) | **-** | **-** | «did not give a credit»  (*do not take into consideration of GPA)* |
| W  (Withdrawal) | - | - | «renunciation of the course»  (*do not take into consideration of GPA)* |
| AW  (Academic Withdrawal) |  |  | Renunciation of the course by academic cause  (*do not take into consideration of GPA)* |
| AU  (Audit) | - | - | «the course is listen»  (*do not take into consideration of GPA)* |
| Атт. |  | 30-60  50-100 | Attested |
| Не атт. |  | 0-29  0-49 | No attested |
| R (Retake) | - | - | Retake the course |

Session № \_\_ of « \_\_ » \_\_\_\_\_\_\_\_\_\_\_ 2013.

**Head of the Department S. Muhambetzhanov**

**Lecturer S. Serovajsky**